Session 16

Mike Salisbury

Ardaman and Associates, Inc.

Improved Storm Surge Anaylsis

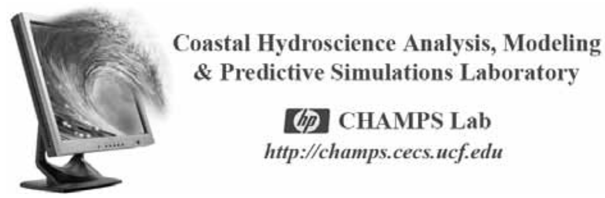
Topic Description

Presentation will discuss the effect that tidal inlets have on open coast storm surge hydrographs. In addition, a storm surge hindcast of Hurricane Ivan (2004) in the vicinity of Escambia Bay will be presented. The results and conclusions have implications toward improved circulation analysis within inlets and bays during extreme events. This research was part of a Design Hurricane Storm Surge Pilot Study that was sponsored by the Florida Department of Transportation.

Speaker Biography

Until recently, I was a Research Scientist in the Coastal Hydroscience Analysis, Modeling, and Predictive Simulations laboratory at the University of Central Florida, where I completed my master's in 2005. During my time in the CHAMPS lab, I had the pleasure of working on numerous coastal hydrodynamic studies throughout the State of Florida. This included, but was not limited to, a storm surge hindcast of the four hurricanes that made landfall along the Florida coast in 2004 (Hurricanes Charley, Frances, Ivan, and Jeanne). My efforts focussed on model calibration and domain sensitivity for each of the four storms. Currently, I am a Water Resources Engineer at Ardaman and Associates in Orlando.

The Effect of Tidal Inlets on Open Coast Storm Surge Hydrographs: A Case Study of Hurricane Ivan (2004)



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University of Central Florida

Acknowledgements

Florida Department of Transportation
- Mr. Rick Renna

University of Florida
- Dr. Max Sheppard
- Dr. Don Slinn
- Dr. Frederique Drullion

University of Central Florida
- Mr. Yuji Funakoshi
- Mr. Peter Bacopoulos

Presentation Outline

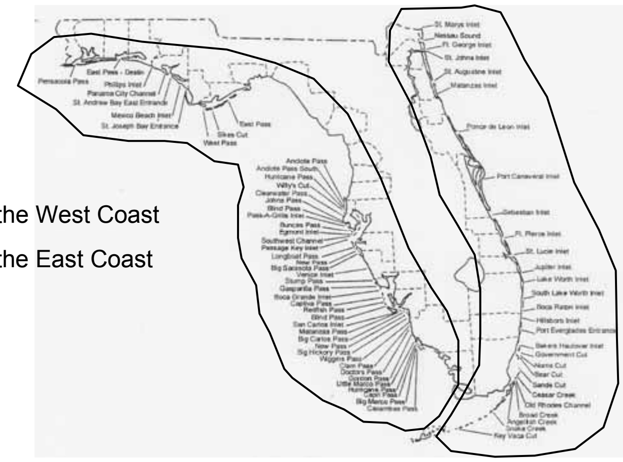
- Project Background
- Tidal Inlets
- Inlet / Bay Relationship
- Finite Element Mesh Generation
- Model Description
- Numerical Parameter Study Results
- Escambia Bay Domain Results
- Conclusions
- Future Work

Project Background

- Local, high resolution models use design storm surge hydrographs along the open coast boundary to compute scour near coastal bridges
- Previous research has indicated that these design conditions vary significantly between government agencies
- FDOT commissioned a pilot study to develop more accurate open coast boundary conditions
- A major part of this study involved examining the effect that tidal inlets have on open coast storm surge hydrographs

Florida's Tidal Inlets

- 46 on the West Coast
- 28 on the East Coast



Source: Carr de Betts, 1999

Tidal Inlets

- Each inlet is typically defined by the following hydraulic variables:
  - Width
  - Depth
  - Length
  - Tidal Prism*
  - Spring Tidal Range
- A wide range of values exist for each variable

* Tidal prism refers to the volume of water that enters the bay during flood tide and exits the bay during ebb tide

Florida Tidal Inlet Statistics

Parameter	Unit	Mean	Standard Deviation
Width	[m]	388	337
Depth	[m]	3.7	2.0
Length	[m]	2257	1814

- The width, depth, and length are used to develop the finite element meshes for the numerical parameter study

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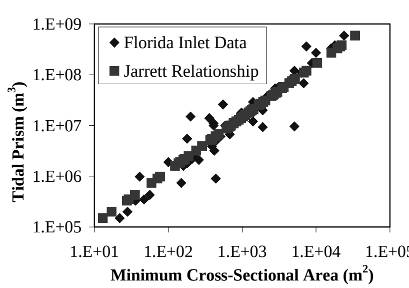
Inlet Cross-Sectional Area - Bay Surface Area Relationship

•Relationship presented by Jarrett (1976): $A_C = 2.09 \times 10^{-5} \Omega^{0.95}$

•Bay Surface Area = Tidal prism / Tidal range

•Assume that the tidal range is 1 meter

$$\therefore \quad Bay\ Area = \left(\frac{A_C}{2.09 \times 10^{-5}} \right)^{1/0.95}$$



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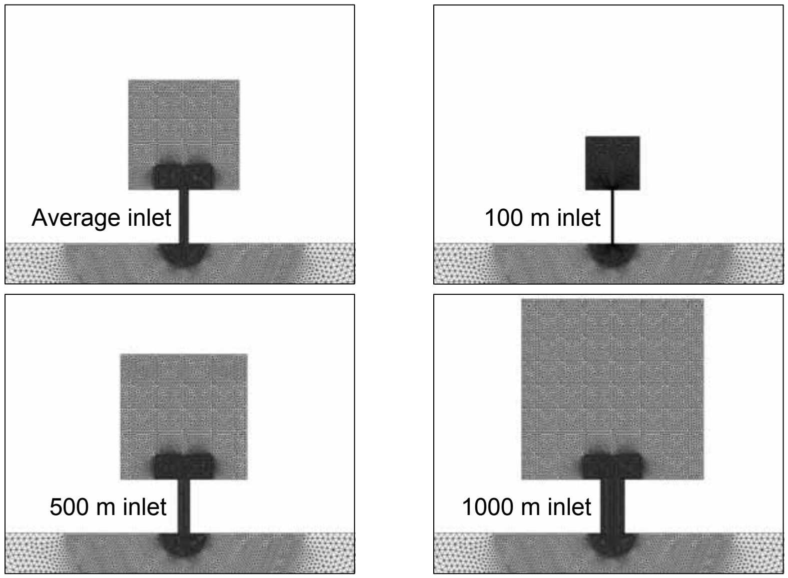
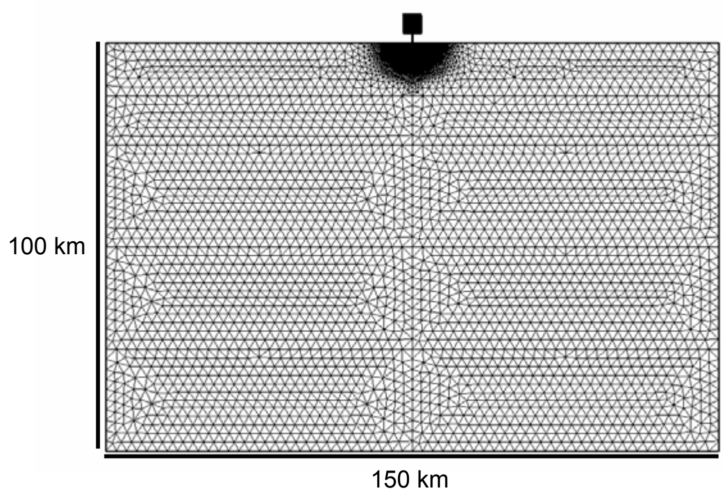


Finite Element Mesh



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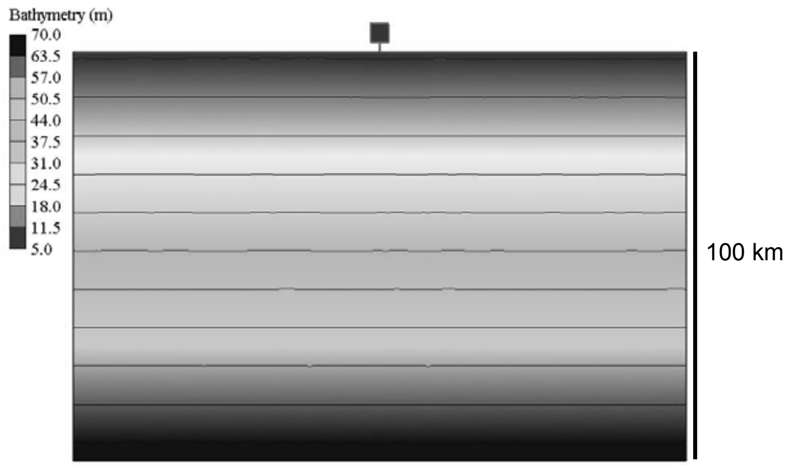
Idealized Bathymetry



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ADCIRC Model

- Advanced Circulation, Two-Dimensional Depth-Integrated (ADCIRC-2DDI) model
  - Long-wave, coastal and ocean circulation model
  - Finite element based
  - Employs the Generalized Wave Continuity Equation (GWCE)
  - Simulates astronomic tides and hurricane storm surge

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Model Parameters

- 4-day simulation time
- 2-day ramp period
- 0.25-sec time step
- Constant Coriolis parameter (corresponding to 27.5°N)
- 1 harmonic forcing: M_2 frequency, 0.5 meter amplitude, 0°phasing
- Horizontal eddy viscosity set to 5 m^2/sec
- Hybrid bottom friction formulation
  - C_{fmin} = 0.0025, H_{break} = 10 m, θ = 10, and λ = 1/3

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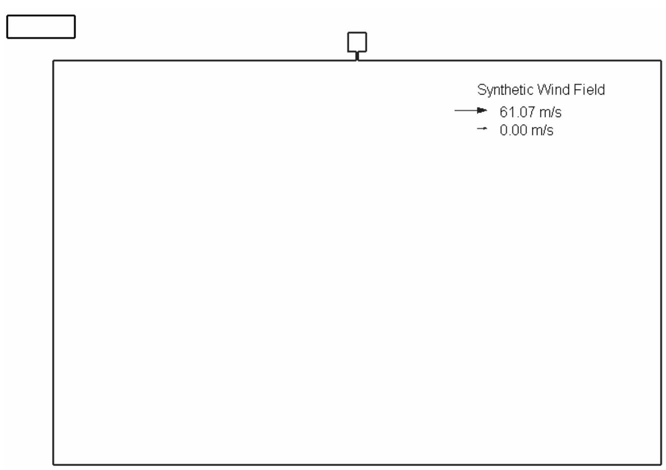
Idealized Wind Field



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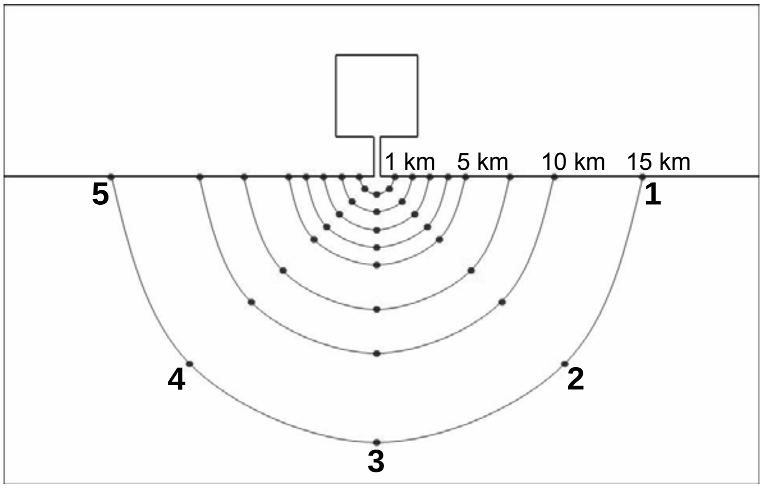
Model Output Locations



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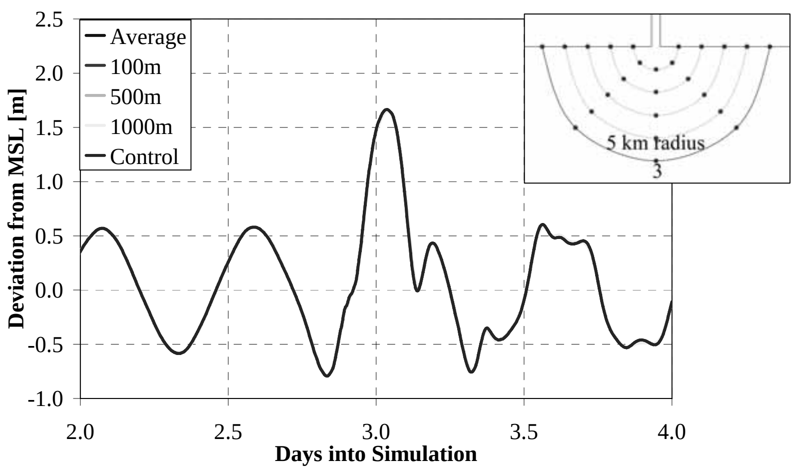
Idealized Inlet Comparison



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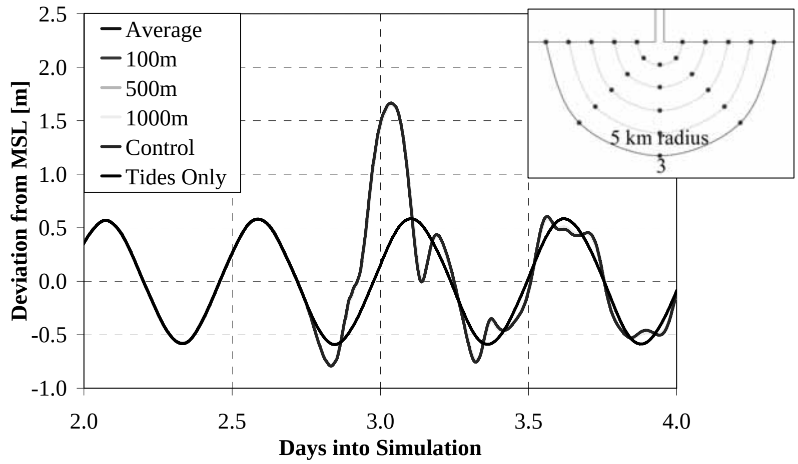

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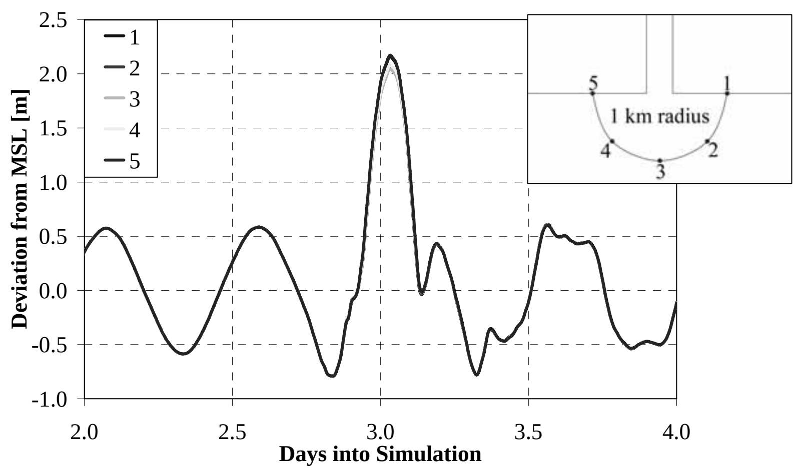
Idealized Inlet Comparison, 1 km radius



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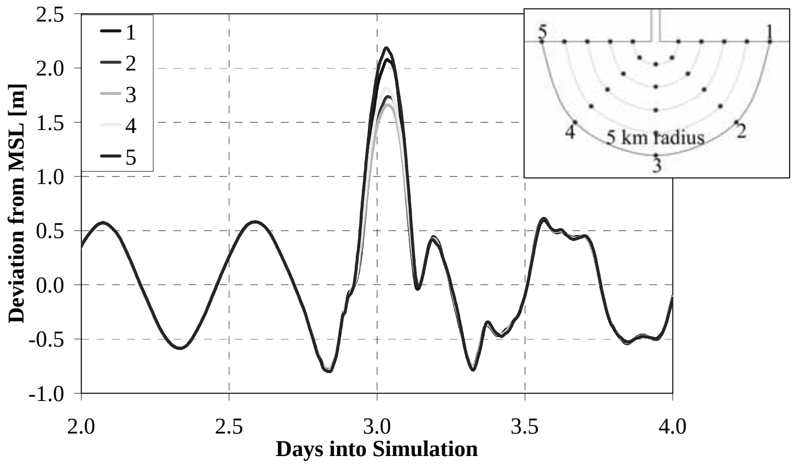
Idealized Inlet Comparison, 5 km radius



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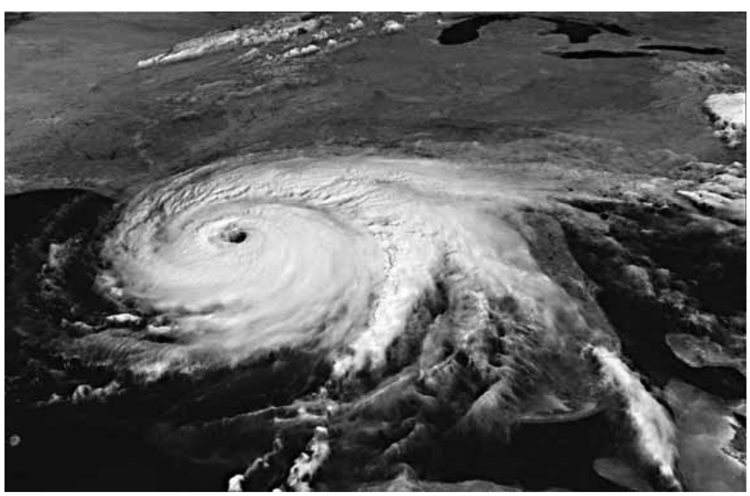
Hurricane Ivan Hindcast



Source: NASA

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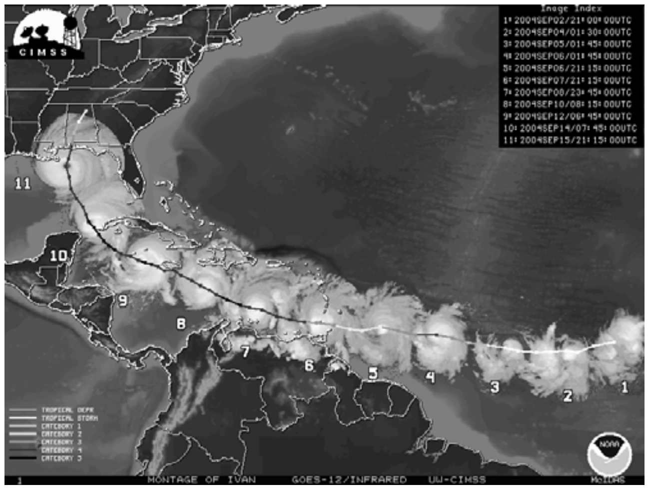
Hurricane Ivan Track



Source: NOAA / NWS

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Hurricane Ivan - Statistics

- Death toll: 92 (25 within the U.S.)
- Damages: $14.2 Billion (Estimated in the U.S.)
- Hurricane Category (Landfall): 3
- Max. Hurricane Category: 5
- Storm Surge: 3-4 m (within bay)
- Min. Pressure: 910 mb
- Pressure at Landfall: 943 mb
- Max. Winds: 185 mph
- Sustained Winds at Landfall: 130 mph

Source: NWS / TPC / National Hurricane Center

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Hurricane Ivan - Damage

Pre-Hurricane Ivan (6/2/04) Post-Hurricane Ivan (9/18/04)

Source: FDEP / Bureau of Beaches and Coastal Systems

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Hurricane Ivan - Damage

¼ mile section of the I-10 bridge crossing Escambia Bay collapsed.

Source: National Weather Service

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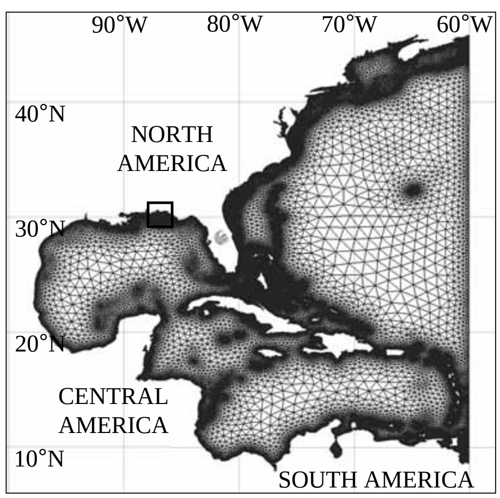
Computational Setup

- Two model domains
  - Ocean-based domain: with barrier islands treated as model boundaries
  - Ocean-based domain: with barrier islands treated as inundation areas
- Same wind field used for each domain
- Similar Escambia Bay features included in each domain

Western North Atlantic Tidal Model Domain



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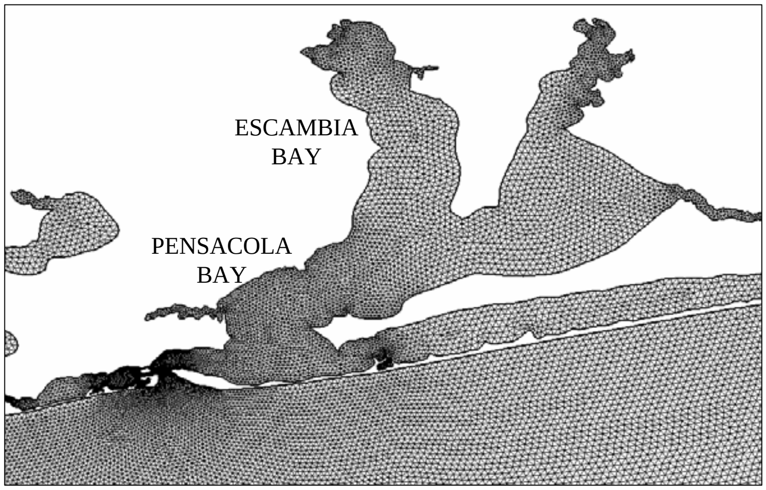
Escambia Bay Discretization



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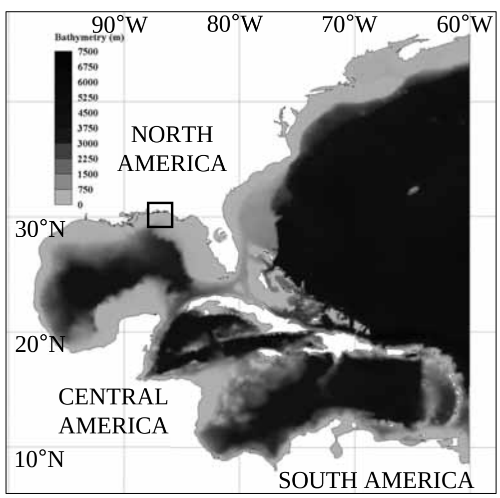
WNAT Bathymetry



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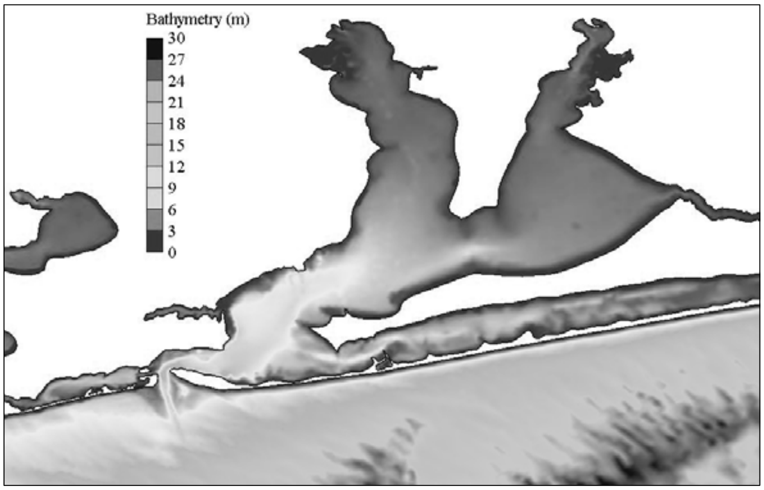
Escambia Bay Bathymetry



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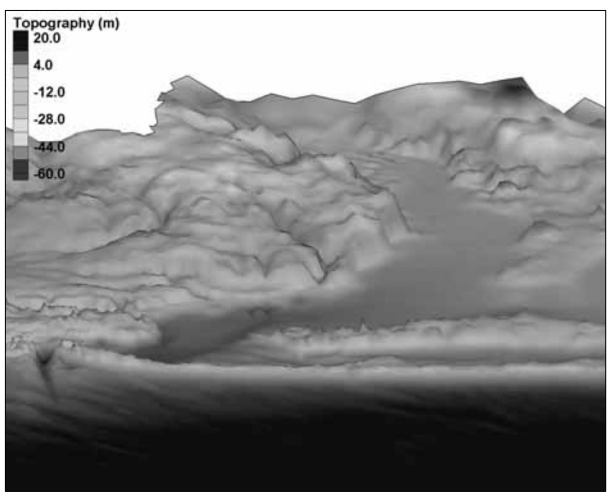
Escambia Bay - Topography



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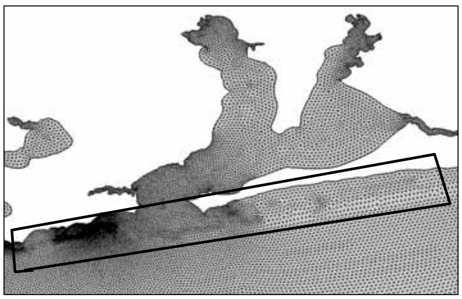
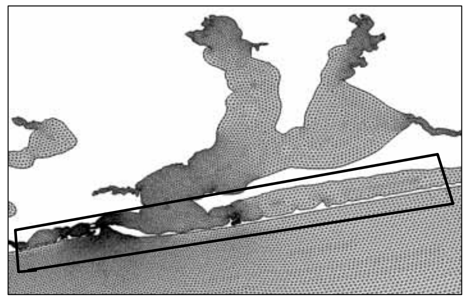
Inundation Areas

Meshed Over Islands



Boundary Islands



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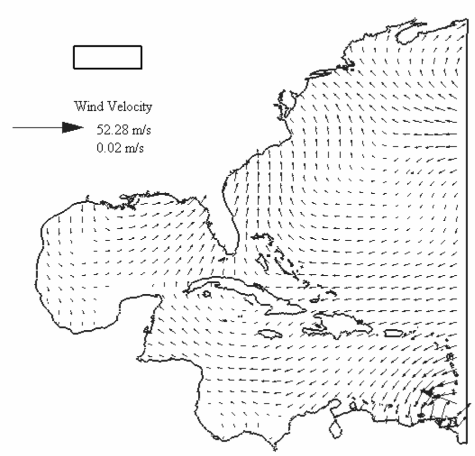
Hurricane Ivan Wind Field



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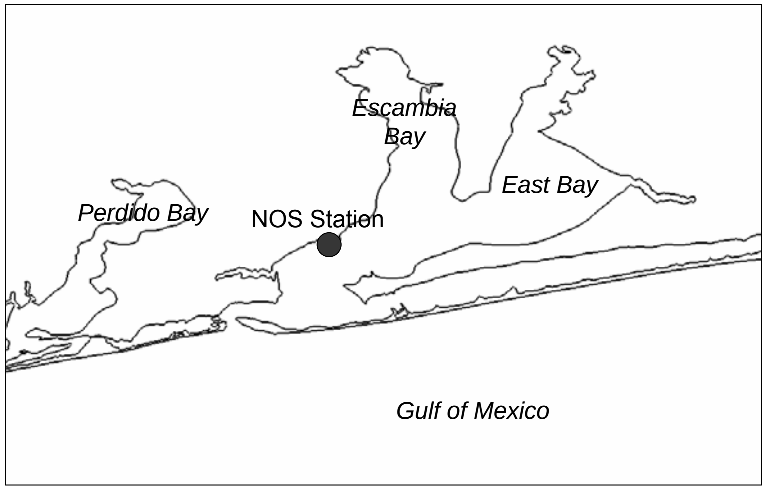
NOS Station in Pensacola Bay



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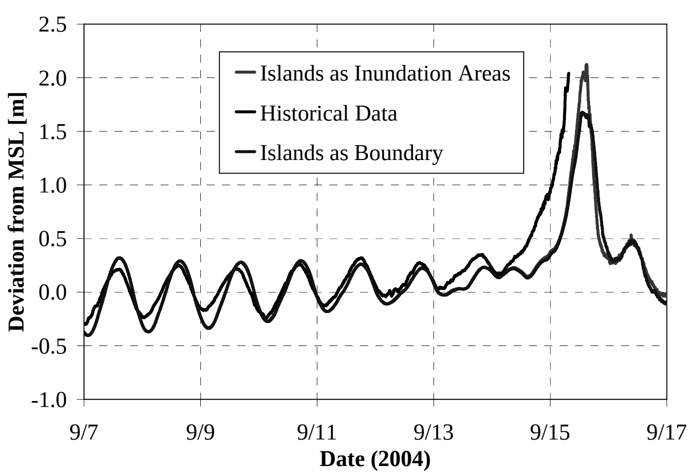
Model Results



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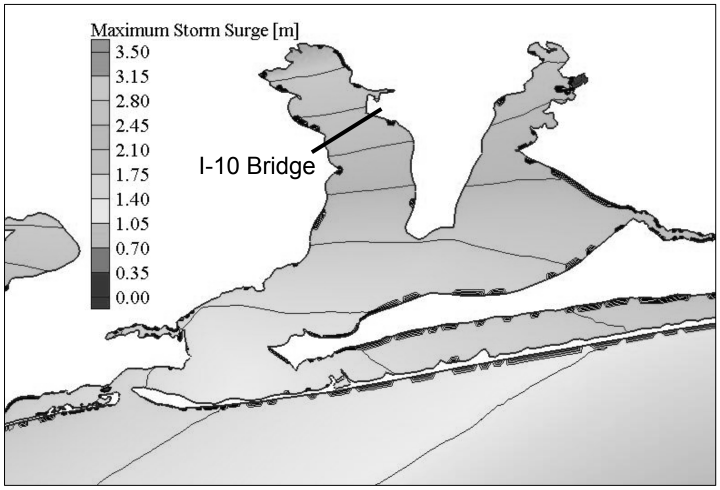
Maximum Surge Contours – Boundary Islands



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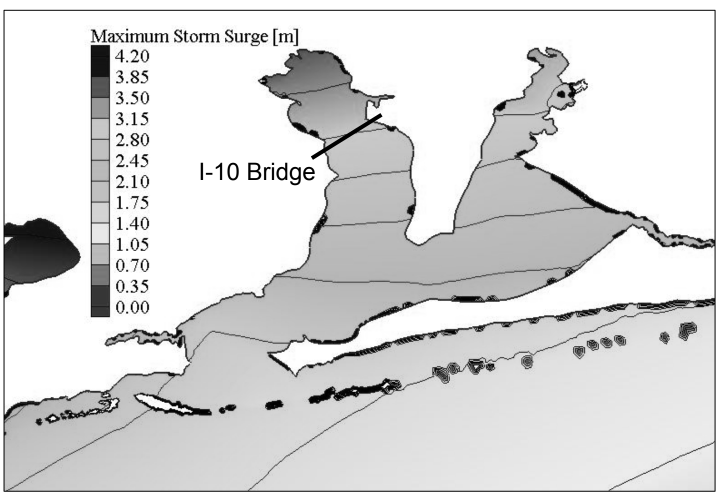
Maximum Surge Contours – Inundation Islands



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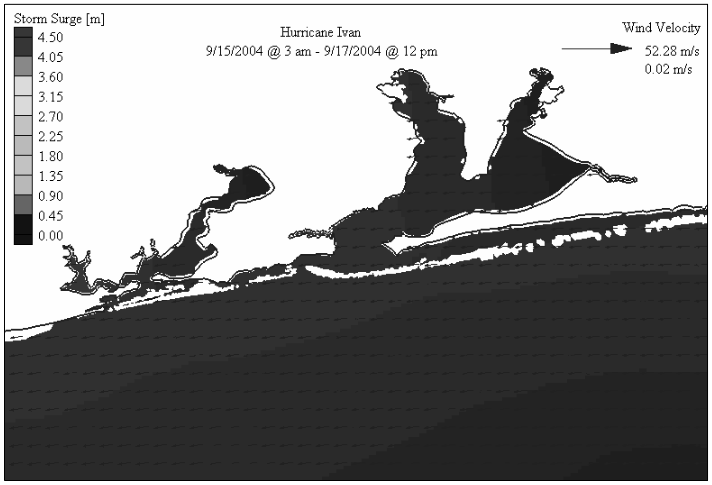
Storm Surge Animation



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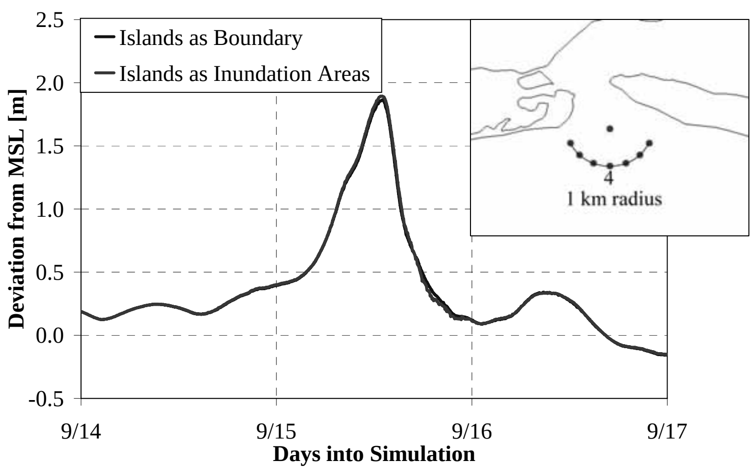
Effect of Inundation Areas on Open Coast Hydrographs



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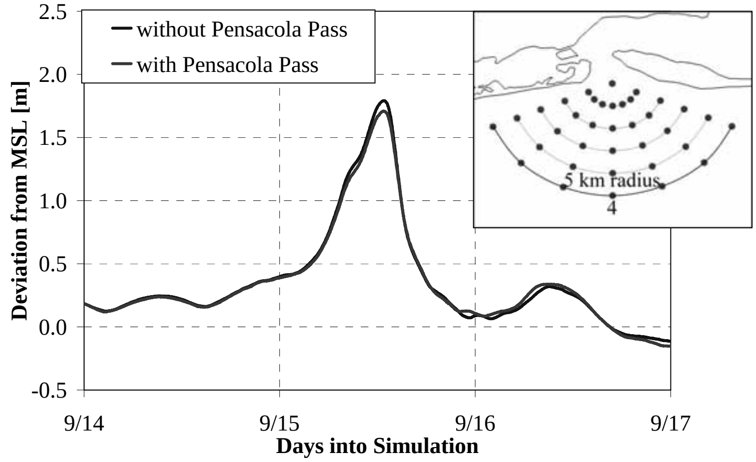
Effect of Pensacola Pass on Open Coast Hydrographs



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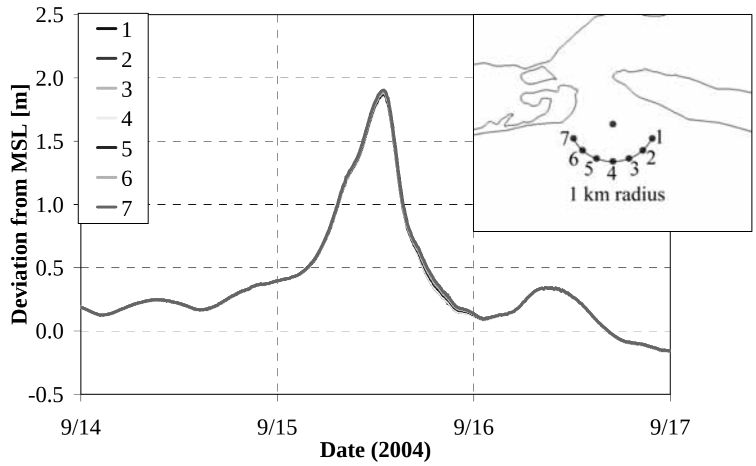
Spatial Variance along the 1 km arc



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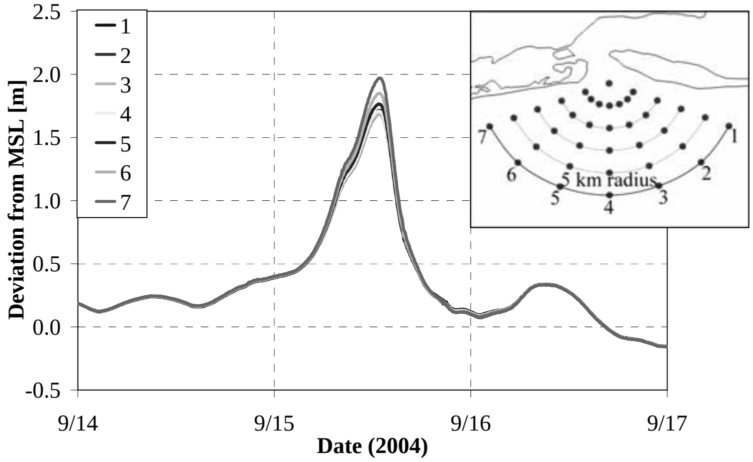
Spatial Variance along the 5 km arc



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Numerical Parameter Study Conclusions

- The effect of tidal inlets on the open coast storm surge hydrographs is minimal
- A spatial variance exists along the open coast boundary locations

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Hurricane Ivan Hindcast Conclusions

- Treating the barrier islands as inundation areas improves surge levels within the bay, but does not have an impact on the open coast hydrographs
- Conclusions from the numerical parameter study are verified for the case of Pensacola Pass during Hurricane Ivan

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On-going Research in the CHAMPS Lab

- Identify optimal model parameters for coastal storm surge simulations
  - Wind drag coefficient
  - Bottom friction coefficient
- Four hurricanes from 2004 provide a good basis for comparison
  - Hurricanes Charley, Frances, Ivan, and Jeanne

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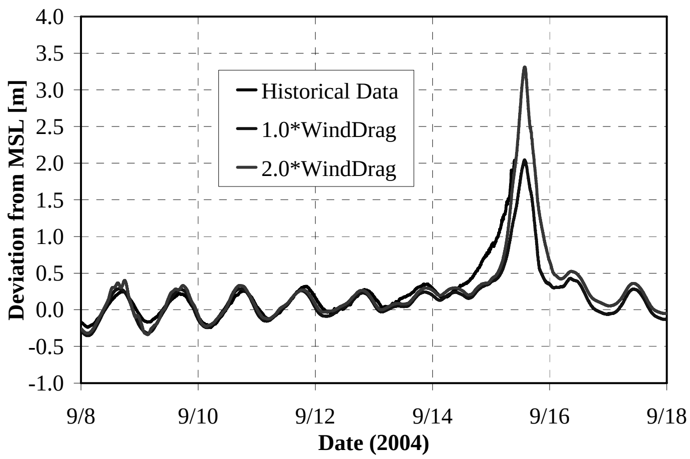
Wind Drag Coefficient Results – Hurricane Ivan



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